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A Rapid Method for Projecting and Measuring Cross Sections of Wool Fibers[1]

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INTRODUCTION

Fineness of wool is the dominant dimensional character affecting its value for commercial purposes. Accurate determination of the fineness and uniformity in diameter of wool fibers depends on the use of the microscope. The two standard methods designated by the American Society for Testing Materials are the cross-section method developed by Hardy (*5*, *6*)[2] and the width method of Lauth (*9*) and von Bergen (*11*, *12*).

Information on the fineness and uniformity of wool is of concern to both the grower and the manufacturer. The control of these characters to meet market and manufacturing requirements is a responsibility of the breeder and the geneticist, yet they seldom have sufficient information for proper guidance in this important problem. Accurate measurement of samples of wool from large numbers of sheep has been limited heretofore because of the amount of time and expense involved.

The speed and simplicity of measuring the fiber diameters directly from a projected image of the cross sections make such a method suitable for wide application. The cross sections can be projected

[1] This work was done at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, N. Mex., under authority of the Bankhead-Jones Act, in cooperation with the Bureau of Indian Affairs, United States Department of the Interior.

[2] Italic numbers in parentheses refer to Literature Cited, p. 10.

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upon an opaque background and measured with either a bidiameter or wedge scale. Such a method is open to some criticism, however, because shadows from the operator's hands and head interfere seriously with measuring the fibers. To overcome this difficulty, Mennerich (*10*) projected the fiber cross sections upon a vertical ground-glass screen. The observer measured the fibers from behind the screen and operated the mechanical stage and fine-focusing screw by a system of remote controls.

Several ways of utilizing the ordinary microscope for projection and drawing are described by Clark (*2, pp. 210–220 and 255–263*). In Europe several instruments have been developed for wool-fiber measurements based on the projection method. The Zeiss lanameter, described by Franz (*4*) and Doehner (*3*), was selected at the International Wool Conference at Warsaw in 1936 as the sole international standard instrument for arbitrational wool-fineness measurement. This instrument is expensive and has been used to a limited extent in the United States.

At the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, N. Mex., wool and genetic research is being conducted with 600 ewes of Navajo and crossbred strains. The Navajo sheep produce a carpet-type wool that is extremely variable in cross-sectional shape and diameter of fiber. The problem of measuring wool samples aggregating 500,000 to 1,000,000 fibers annually with a limited personnel appeared insurmountable. Furthermore, studies to determine the characteristics of wools best adapted for Navajo weaving involved the measurements of thousands of dyed or natural-color fibers from the choice old hand-woven blankets and rugs. These opaque cross sections could not be photographed on ordinary sensitized paper, and the use of panchromatic film would have been slow and expensive.

A simple, inexpensive method was developed for projecting the image of the cross sections, at high magnification, upon a horizontal ground-glass screen. Rapid measurement of the cross sections is accomplished by means of an improved bidiameter scale. Either a microprojector or an ordinary microscope may be adapted to this method at small cost. With samples of white wool, as many as 4,000 fibers can be sectioned and measured daily by an experienced operator and a recorder.

METHOD OF OPERATION WITH THE MICROPROJECTOR

Figure 1 shows the microprojector (*a*) mounted in a cabinet (*h*) of suitable dimensions. The projector is equipped with a transformer for use with a 6-volt, 108-watt lamp and a triple condenser for critical illumination. Other necessary accessories include the mechanical stage (*b*), standard set of objectives and oculars, and right-angle prism (*d*), which fits over the eyepiece and deflects the image in a vertical direction. For a magnification of 500 times, the 8-mm. objective and 10X ocular are used with a projection distance of 57.8 cm. The magnification may be checked with a stage micrometer graduated to 0.01 mm. A Howard eyepiece micrometer disk ruled in squares equal to one-sixth the diaphragm opening of the ocular is used to facilitate systematic and rapid measurement of the fibers.

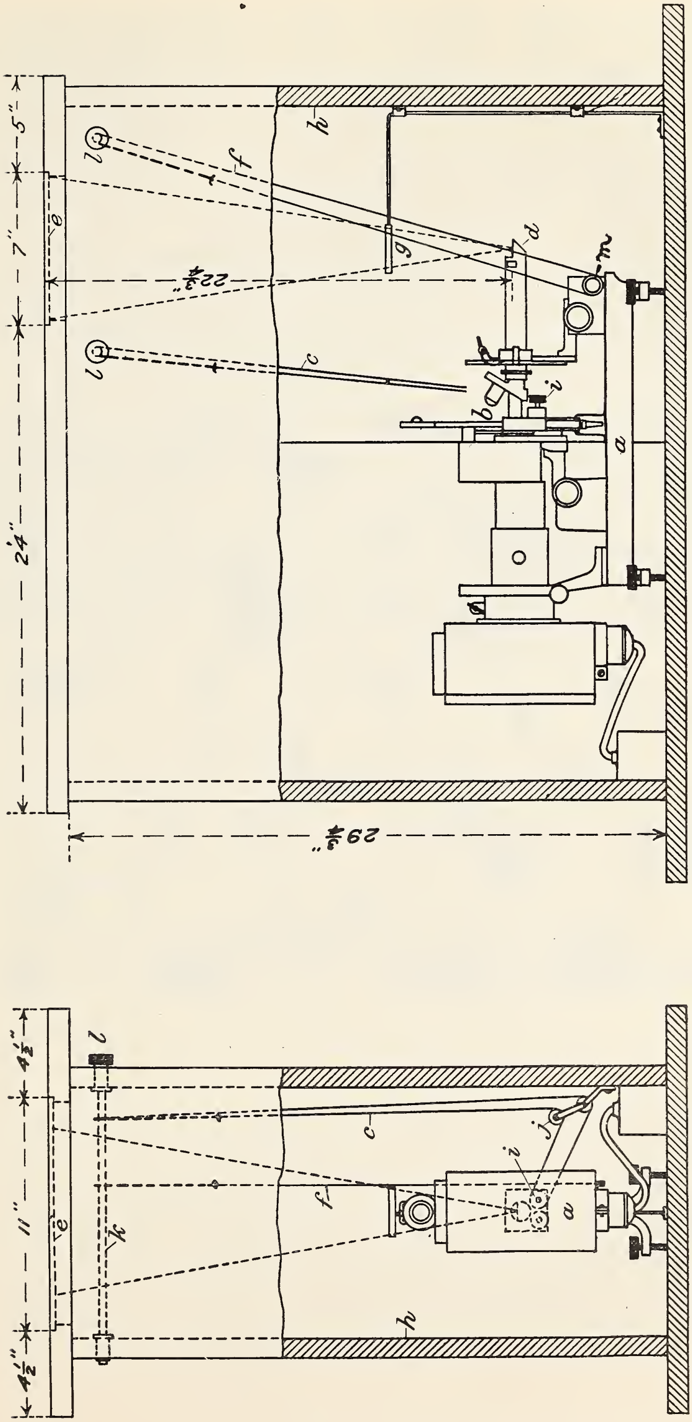

FIGURE 1.—Method of projecting cross sections of wool fibers on a horizontal ground-glass screen, as shown by end and side views. The parts of this apparatus are as follows: *a*, Microprojector; *b*, mechanical stage; *c*, cord; *d*, prism; *e*, ground glass; *f*, cord; *g*, filter; *h*, cabinet; *i*, horizontal adjustment for mechanical stage; *j*, pulley; *k*, horizontal rods; *l*, controls; *m*, fine-focusing screw.

The magnified image of the cross sections is projected to the 7×11-inch ground-glass screen (*e*) located in the top of the cabinet. The magnified image of the eyepiece disk divides the microscopic field into sections 48 mm. square, as shown in figure 2. Each square usually contains from 6 to 15 fiber cross sections, the number varying according to the fineness of the wool and the packing of the fibers in the slot of the device. Beginning in the lower left-hand corner of the field and working from left to right, all fibers are measured in each full square. Some of the fiber sections around the borders of each square extend over into adjacent squares. To insure that all fibers are measured systematically, the following rule is used: Fibers lying half or more inside the line demarking the field are measured, whereas fibers lying more than half outside are not measured. The latter fibers are thus automatically included in an adjacent square.

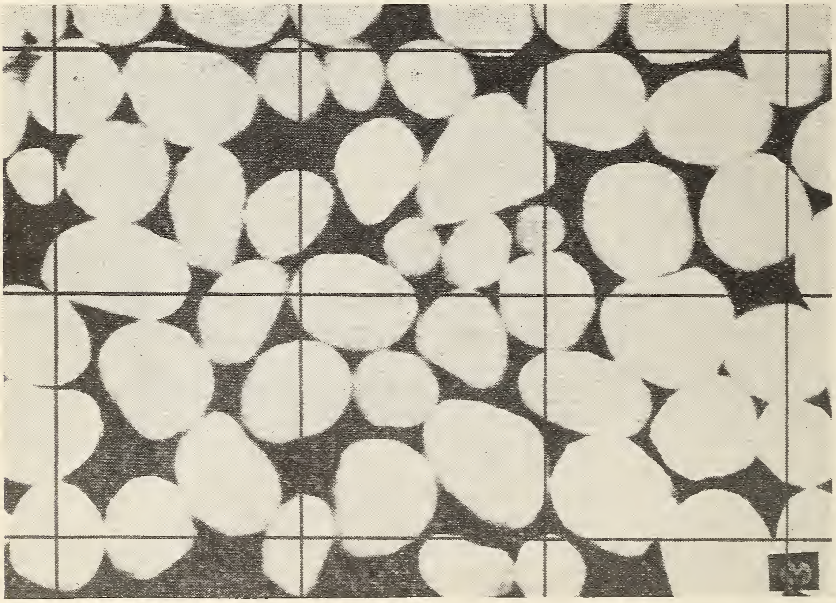

FIGURE 2.—Portion of the fiber cross sections projected on the ground-glass screen. ×500. The microscopic field is divided into squares by the image of the lines on the eyepiece micrometer disk.

The operator measures the fibers from a convenient sitting position (fig. 3). Fatigue is further reduced by the fact that the arms are supported in a natural position by the cabinet top. The horizontal adjustment (*i*) of the mechanical stage (*b*) and the fine-focusing adjustment (*m*) are operated from remote controls (*l*) located on the exterior of the cabinet near the ground-glass screen. Operation of the adjustments is accomplished by means of two drive cords (*c*) and (*f*) connecting with horizontal rods (*k*) in the top of the cabinet. The cord (*c*) fits over the horizontal adjuster (*i*) of the mechanical stage and passes through the pulley (*j*), as shown in the end view.

FIGURE 3.—Measuring the projected cross sections (right) and recording the measurements by an assistant (left).

The two ends of each cord are joined by a heavy rubber band to equalize tension. An amber-light filter, equal in depth of color to a Wrattan G No. 15, is used in the holder (*g*) to reduce glare and improve definition of the cross-section images.

ADAPTING THE MICROSCOPE FOR PROJECTION USE

A single-tube compound microscope can be used to advantage for projecting cross sections of the fibers, as shown by figure 4. The simplicity and inexpensiveness of this arrangement are factors of first consideration. The microscope (*a*) is bent over in a horizontal position with the base securely held in place by clamp (*n*). The method of operation is similar to that described for figure 1. A source of light of high intensity, such as the 6-volt, 108-watt lamp used in the microprojector, is essential. The lamp (*m*) is placed at the correct focal distance to obtain a fine point of light, which is centered on the objective. The substage mirror is removed from its normal position and mounted as shown by (*d*), with the flat surface at an angle of 45° to the ocular. The mirror serves the same purpose as the right-angle prism on the microprojector. A metal tube may be used to connect the lamp and substage condenser and thus prevent stray light from fogging the microscopic image when projected on the ground-glass screen.

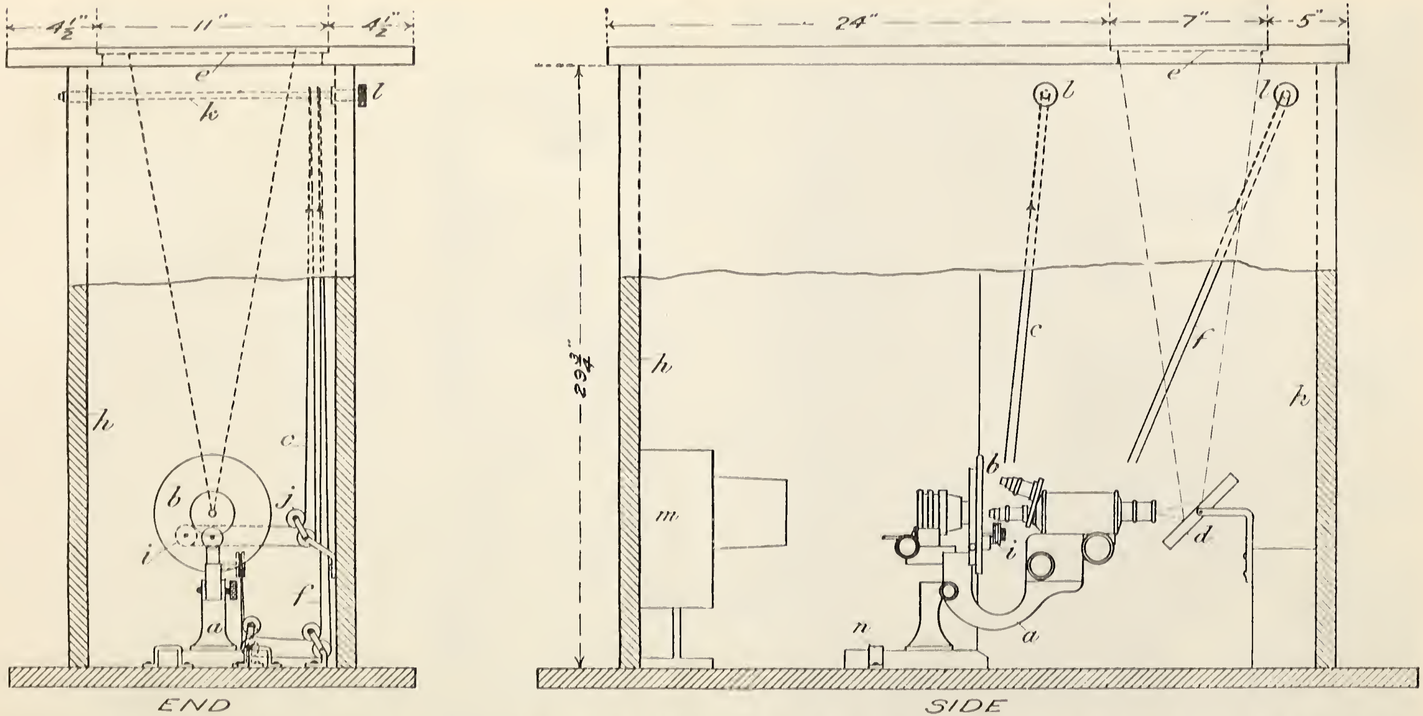

FIGURE 4.—Manner in which a compound microscope can be adapted for projection of cross sections of wool fibers, as described for figure 1 (end and side views shown). The apparatus includes: *a*, Microscope; *b*, mechanical stage; *c*, cord; *d*, mirror; *e*, ground glass; *f*, cord; *h*, cabinet; *i*, horizontal adjustment for mechanical stage; *j*, pulley; *k*, horizontal rods; *l*, controls; *m*, lamp; *n*, clamp holding microscope.

Adaptation of the microscope as illustrated gives a brighter projection than if used in a normal vertical position and illuminated by reflected light from the substage mirror, as described by Berndt (*1*). He used a microscope for projecting and measuring blood cells. Remote controls for focusing the specimen and operating the mechanical stage consisted of rods equipped with a universal joint-and-socket grip.

PREPARATION OF CROSS SECTIONS

In the preparation of thick cross sections of translucent fibers, as described by Hardy (*6*), a drop of black celluloid solution or India ink may be used to fill in the spaces between the fibers and improve definition of the cross sections. India ink contains water, which may cause a slight swelling of the fibers, and for this reason the celluloid solution is preferable for photomicrographic work or when maximum accuracy in measurement is desired. The opaque liquid is applied after the projecting ends of the fibers have first been cut off with a sharp safety-razor blade. A drop of the solution is spread on one side of the section, allowed to dry, and then sliced off close to the metal surface of the device. The sections of the fibers then show clearly on a dark background. The cross-section device is next placed in the mechanical stage, and the vertical adjuster is used to locate the image of the fiber cross sections on the ground glass. The operator seats himself at the end of the cabinet and rotates the remote control of the mechanical stage, moving the microscopic image in a horizontal plane until the end of the section comes into view. The image is then focused sharply by a light turn of the other remote-control knob, which rotates the fine-focusing screw.

USE OF IMPROVED BIDIAMETER SCALE

For measuring the fiber cross sections, the improved bidiameter scale illustrated in figure 5 is used. This scale is a modification of the one described by Mennerich (*10*). It is graduated in millimeters, 1 mm. being equal to 2μ at a magnification of 500. The scale is placed over the image of the fiber cross section with the vertical base line tangent to the periphery of the fiber along its major axis. The horizontal base line will then be tangent to the periphery of the fiber along its minor axis. The average diameter is read directly in microns by simple addition of the minor and major widths of the fiber as measured in millimeters. The fibers can be measured to the nearest micron by interpolating between lines. However, this procedure is not recommended because it introduces a source of error. For maximum accuracy, all fiber measurements should be confined to the six squares nearest the center of the field. Magnification is about 2 percent greater outside this specified area.

The average diameters of the fibers can be measured as rapidly with the improved bidiameter scale as the single width of the fiber is measured with other scales generally used. The greater accuracy of the average diameter, particularly for wools with a high degree of ovality or irregularity in shape of fiber, can be readily recognized.

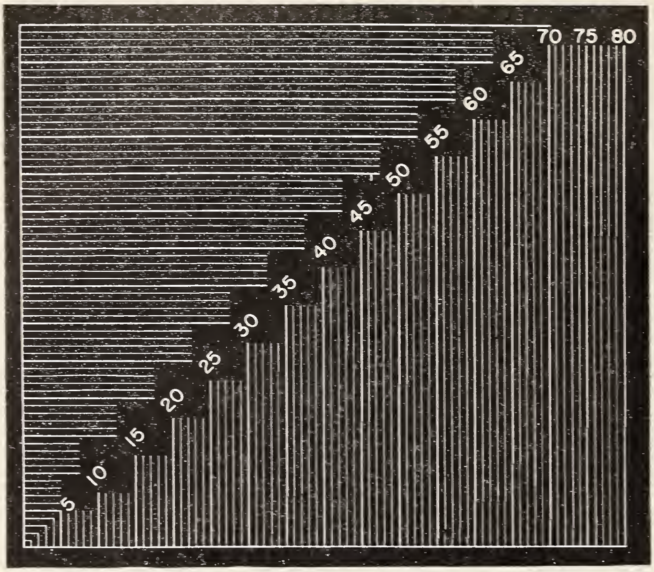

FIGURE 5.—Improved bidiameter scale graduated in millimeters. Average diameter of a fiber, in microns, is obtained by addition of the major and minor widths, since 1 mm. on the scale equals 2μ at a magnification of 500.

When the major and minor axes of a fiber deviate to any considerable extent from a right angle, it is necessary to make two or more measurements of each width and use the average. Thin cross sections of dyed or natural-colored fibers, prepared by the technique described by Hardy (*7*), are also projected and measured by the method just described.

RECORDING FIBER DIAMETERS AND CALCULATING BY MACHINE

A standard record form is used for the fiber-diameter measurements. The date, breed of sheep, eartag number, year of birth, age at sampling, position from which sample was taken, and magnification of the cross section are recorded in this form. Space is provided on the measurement sheets for recording all statistical values obtained from the machine calculations. This procedure facilitates further statistical study.

An assistant records the fiber diameters in the form of a frequency distribution. The frequencies are also recorded simultaneously on a mechanical counter so that the operator will know when the required number of fibers has been measured.

The occurrence of kemp and medullated fibers in each wool sample is recorded by a system of symbols. Kemp is identified by (k) and the relative size of medullation in other types of fibers as large (l), medium (m), and small (s). The symbols are written adjacent to their corresponding diameter frequencies. This record provides not

only a quantitative measure of these characteristics, but also aids in relating medullation to the types of fibers in which it occurs.

The frequency distributions facilitate rapid comparison of the wool samples for range in diameter and percentage of fibers in class intervals of any size desired. The measurements are also in the most suitable form for rapid machine calculation of such statistical values as the arithmetic mean, standard error of the mean, standard deviation, and coefficient of variation.

With a 10-bank keyboard machine the calculations can be made in from 3 to 5 minutes, depending on the diameter dispersion of the sample. Each diameter represented in the distribution is punched in the right side of the keyboard, its square on the left side, and multiplied by the frequency. The sum, sum of squares, and total number of fibers are accumulated simultaneously. If the operator is experienced in the use of the machine, he can make the calculations while his partner prepares the cross section of a new sample.

OTHER USES OF THE PROJECTION APPARATUS

The projection method described is also suitable for rapid examination and measurement, at high magnification, of cross sections or longitudinal mounts of other textile fibers, fur fibers, hair, and bristles. Photomicrographs can be made by replacing the ground-glass screen in the cabinet top with high-quality clear glass of similar size. The image is projected on sensitized paper or cut film placed with the emulsion side in contact with the glass.

The projected image of a cross section of fibers of unknown fineness and uniformity may be compared with photomicrographs of standard samples. This can be accomplished by attaching to the cabinet, parallel to the ground-glass field, a revolving shaft supporting a hexagonal frame 6 by 12 inches on a side. Each side of the hexagon is grooved to accommodate a clear celluloid card 0.015 inch thick, on which is mounted a cross-section photomicrograph. A light centrally located in the axis of the hexagon will illuminate each photomicrograph so that it may be compared with the image of the projected cross section. A special apparatus of this type has been described and illustrated by Hardy and Wolf (*8*).

The magnification may be modified as desired for the rapid examination and study of histological and cytological slides. It is especially adapted for the counting and measuring of various types of cells.

Drawings may easily be obtained by placing tracing paper on the ground-glass screen and tracing the outlines of the projected image.

SUMMARY

A simple and inexpensive method for projecting cross sections of wool fibers on a horizontal ground-glass screen is described and illustrated. Either a microprojector or ordinary microscope may be used. The mechanical stage and fine-focusing adjustment are operated from remote controls. The fibers are measured from a convenient sitting position, with the arms supported by the cabinet top.

An improved bidiameter scale for measuring the average diameters of the fibers is described and illustrated. As many as 4,000 fibers can be cross-sectioned and measured daily by an experienced operator and a recorder. Methods of recording and evaluating the measurements are outlined.

The projection apparatus may also be used for the examination and measurement of other textile fibers, fur fibers, hair, and bristles.

LITERATURE CITED

(1) Berndt, E.
1929. PHYSIKALISCHE BLUTUNTERSUCHUNGEN, IHR WERT FÜR BEURTEILUNG DER KONSTITUTION UND LEISTUNGSFÄHIGKEIT UND EIN BEITRAG ZUR BLUTGRUPPENBESTIMMUNG ZUM ZWECKE DES INDIVIDUALITÄTSNACHWEISES. Inst. f. Tierzucht und Milchw., Leipzig Univ., Abhandl., Heft 21, illus.

(2) Clark, Charles H.
1925. PRACTICAL METHODS IN MICROSCOPY. Ed. 5, rev. and enl., 337 pp., illus. Boston, New York, etc.

(3) Doehner, H.
1926. EINE NEUE METHODE ZUR FEINHEITSBESTIMMUNG VON EINZELNEN WOOLHAAREN UND DER SORTIMENTSBESTIMMUNG VON WOLLPROBEN. Ztschr. f. Züchtungskunde 1: 282–295.

(4) Franz, E.
1937. DAS ZEISS LANAMETER FÜR WOLLFEINHEITSMESSUNGEN. Melliand Textil Ber. 18: 557–558, illus.

(5) Hardy, J. I.
1933. DETERMINATION OF FIBRE FINENESS. A RAPID METHOD USING A NEW CROSS-SECTIONING DEVICE. Textile Res. 3: 381–387, illus.

(6) ———
1935. DETERMINATION OF FIBRE FINENESS AND CROSS-SECTIONAL VARIABILITY. . . . Textile Res. 5: 184–190, illus.

(7) ———
1935. A PRACTICAL LABORATORY METHOD OF MAKING THIN CROSS SECTIONS OF FIBERS. U. S. Dept. Agr. Cir. 378, 11 pp., illus.

(8) ——— and Wolf, H. W.
1939. TWO RAPID METHODS FOR ESTIMATING FINENESS AND CROSS-SECTIONAL VARIABILITY OF WOOL. U. S. Dept. Agr. Cir. 543, 16 pp., illus.

(9) Lauth, E.
1930. A NEUE MITTEL ZUR FEINHEITS-LÄNGEN-UND KRAFTBEWERTUNG VON KAMMWOLLEN. 63 pp. Munich.

(10) Mennerich, Fred A.
1936. RAPID MICROSCOPAL MEASUREMENT OF DIAMETERS IN CROSS-SECTION. Textile Res. 6: 217–222, illus.

(11) Von Bergen, W.
1932. MEASUREMENT OF FIBER WIDTHS BY THE WEDGE METHOD. Melliand Textile Monthly 6: 182–184, 238–240, 428–431, 486–487, illus.

(12) ———
1935. TESTING THE PHYSICAL AND CHEMICAL PROPERTIES OF WOOL BY MEANS OF THE MICROSCOPE. Amer. Soc. Testing Mater. Proc. 35: 705–726, illus.

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